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ABSTRACT

Online searching is a complex problem solving task requiring the searcher to combine multiple sets into Boolean expressions. Since spatial ability has been correlated with problem solving tasks which involve abstract conceptual associations, this report argues that it is a significant factor in the information user's ability to both comprehend and learn human-computer interface (HCI) search dynamics. Applications of route spatial knowledge (i.e., the memory of a sequence of events or the knowledge to execute a given task) and survey spatial knowledge (i.e., the global perspective of the network of events that organizes an activity or task) are evaluated and compared, and the use of spatial imagery in storing and retrieving semantic information is described. Individual differences in spatial ability, which compound the complexity of the system design task, are explored. It is concluded that powerful interface software that addresses human cognitive factors needs to be developed. It is projected that, once this has been achieved, the ability to capture and code expert searcher algorithms and expert intermediary interview techniques, and to put all of this capability and knowledge into a dynamic interface, will probably not be far in the future. (14 references) (SD)

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SPATIAL ABILITY, IMAGERY AND HUMAN-COMPUTER SEARCH DYNAMICS

by

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Online Information '38
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SPATIAL ABILITY, IMAGERY AND HUMAN-COMPUTER SEARCH DYNAMICS

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Keywords: Spatial Ability, Imagery, Human-Computer Interaction, Online Searching, Cognitive Factors, Human-Computer Interface.

Abstract: Online searching is a complex problem solving task requiring the searcher to combine multiple sets into logical Boolean expressions. Since spatial ability has been correlated with problem solving tasks which involve abstract conceptual associations, the notion is presented that it is a significant cognitive factor in human-computer search dynamics.

1 INTRODUCTION

Art imitates nature and necessity is the mother of invention.
- Richard Franck, c1658

The investigation of human spatial abilities, like most areas of inquiry, is driven by technical and social demands; or as the saying simply states "...necessity is the mother of invention." Indeed, the other half of this famous late Seventeenth Century cannonism is also apropos to the human-computer interface (HCI); and that is "Art imitates nature..." Computer systems are, of course, very anthropomorphic in design as we attempt to create the "Second Self" (Ref.1.).

However, the discussion presented in this paper will not emphasize design issues, but rather will focus on spatial abilities as a factor in the user's ability to both comprehend and learn HCI search dynamics. The investigation of spatial abilities has been demand-related, with work examining individual differences beginning early in this century. These efforts were concerned mostly with prediction of proficiency with tool use. During the First World War the field expanded to "nonverbal intelligence" as a predictor of "mechanical aptitude". The evaluation of spatial abilities in relation to mathematical ability began to take shape after World War II and has since been implicated in such obvious activities as chess and music (see Ref.2. for a good historical account).

More recently, there have been a number of investigators who are correlating spatial ability as an intrinsic cognitive process for abstraction in general. It is a cognitive factor which is involved in physical orientation as well as a mechanism which is involved in symbolic logic, propositional reasoning, and reasoning and memory processes in general (Refs. 3 & 4.).

There has been, however, little attention given to spatial ability in relation to online searching, but by no means has it been ignored. I

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believe, as mentioned, that this is because serious interest in an activity is based on a problem and the ability to do something about it. It seems evident that the difficulty of online searching and a profound increase in access to databases through mass distribution establishes the former; and the availability of vast power from 32 bit word microcomputers makes reasonable the latter.

George Miller was possibly the first or at least one of the first to call attention to the need to spatially orient our users in a computerized search environment when he recognized that computers would eventually dominate information retrieval (Ref.5.). Bennett elaborated on the spatial theme at one of the first conferences on interactive bibliographic searching (Ref.6.). Further, I presented my arguments for the possibility of spatial abilities as a limiting factor in searching when I was able to define a prescriptive and rigorous strategy for the dialogue process (Ref.7.).

The strategy provides a means for adding syntactical structure to the entire dialogue allowing discrete contrast among successive search statements generated through the process of iteration. We will see in the following section that the basic operation of utilizing the NOT Boolean operator for set contrast is part of what is considered "route spatial knowledge" and the "global" syntactical analysis of an entire search is what can be considered "survey spatial knowledge."

2 SPATIAL KNOWLEDGE

The general consensus on spatial knowledge is that it can be categorized in two parts: route and survey (Ref.8.). Route spatial knowledge is the memory of a sequence of events that take place during a given activity or the knowledge to execute a given task, when appropriate. These may be instructions that guide a user along a physical path or an intellectual one, such as through a computer dialogue.

Survey spatial knowledge is the global perspective of the network of events that organizes the activity or task. It is this knowledge which allows a person to understand relationships of various parts of the network regardless of their position. In online searching it would be route knowledge that would guide a user to formulate sets for the dialogue and conceivably survey knowledge that would allow the searcher to "view" the set history effectively. A user could have good route knowledge which would allow effective searching, in other words, to move from statement to statement; but it would be survey knowledge or the ability to say compile the information from twenty search statements to make twenty-one, that would distinguish the expert searcher!

As one would expect and research confirms, survey knowledge is dependent upon route knowledge. Thorndyke experimented with users attempting to learn a new environment (the physical layout of a building at the Rand Corporation) showing that a user goes through an assimilation stage of encoding route knowledge to obtain survey knowledge. He refers to route kpowledge as landmarks or procedures, calling them perceptual icons (Ref.9.).

In the assimilation, the icons are replaced with symbolic abstraction which manifests as knowledge of the survey type. The shift is from short term memory to long term and the transition is crucial since the limits of short term memory preclude any substantial global analysis; the latter being rendered to long term memory and survey knowledge.

The process is one of making the icon automatic, not requiring the user to visualize, perhaps not even to think consciously about it. Take for example the task above with the twenty search statement set history. Experienced searchers who are able to compile this information will have

the spatial survey knowledge which allows them to concentrate on conceptual associations of combinatorial arrays. The capacity for spatial survey knowledge will limit the "problem solving domain" and hence determine the amount of complexity the user can negotiate (Ref.10.). In other words, survey knowledge will determine the problem solving domain, which in turn will limit both a qualitative predicate analysis of associations as well as the quantitative degree of combinatorial arrays the user can include in this domain.

In contrast, a perceptual icon of the route type would be knowledge of how Boolean operators are to be applied, or the tactical use of field qualifiers, etc. For example, this would be knowledge that a term qualified by title, descriptor or as textword will increase in yield respectively but decrease in precision. It is surely not a question which comes to mind for the expert; yet it is exactly this type of knowledge that needs to be assimilated into long term memory to be an expert.

3 SPATIAL IMAGERY

The above model of spatial knowledge corroborates well with evidence which strongly implicates the use of imagery in storing and retrieving semantic information, e.g., abstract propositions. Kosslyn was able to show that the use of imagery is a basic mechanism humans use in the information retrieval process with memory. He compared children and adults for their reaction time to determine whether various animals are characterized by certain properties, e.g., cat-whiskers, collie-horns (Ref.11.).

When subjects based their judgements on consultation of a visual image as instructed, adults were only slightly faster. When imagery was not requested, adults' reaction time occurred much more quickly. Further, in Thorndyke's study, he notes that as symbolic abstraction replaces perceptual icons, attention to visual details diminishes, which is consistent with rapid association and rapid recall of abstract propositions.

These distinctions between child and adult go beyond mere child development since the process of using imagery to put knowledge into long term memory appears to be intrinsic throughout adulthood. Indeed, Thorndyke observed that those who were successful in spatial knowledge acquisition, the "good learners" used imagery and analogy; and those who were unsuccessful, did not! It is suggested further that how one acquires this knowledge will determine how effectively it can be applied. Thus, performance on reasoning tasks will be predicated on the kind of experience that has contributed to an individual's spatial knowledge.

4 SPATIAL ABILITIES AND INDIVIDUAL DIFFERENCES

The implications of the discussion above are quite significant. We are about to witness a rather remarkable new element in the online revolution. For two decades the "revolution" has been going through its "lag phase" somewhat like the exponential growth of bacteria in a flask. These two decades have been the era of the "intermediary," the experts who have gained their survey knowledge from hundreds or thousands of hours of online searching experience. The stage is being set however, with compact disks and locally mounted databases for the end-user to cause the revolution to enter its "burst" phase of development.

Accordingly, it becomes vitally important for interface design to reduce the experiential time necessary for a user to achieve an effective survey knowledge status. Furthermore, individual differences in spatial ability do exist; this certainly compounds the design task, since an interface should take both effective as well as affective action in executing a

dialogue for a user's demands and continuing learning development. An ideal system would perform an initial search for the user, with instruction on how the result was obtained, and then provide options for continuation. Further, it is possible to normalize, or reduce the effect of individual differences in spatial ability in analogical problem solving (Ref.12.). Hence it is quite conceivable that this normalization can also be achieved via an interface design with syntactically structured displays (Refs.10 & 13.).

Soderston explains that a display screen, a digital presentation of information, is "perceptually divorced" from its surrounding environment (Ref.14). If we take the example of literature searching, the task is broken down into individual frames of information on a screen which have logical links, but not the continuity that exists in performing the task with a printed volume or a card catalog. Printed volumes and card catalogs provide the user with a reference point, a concrete identification of where information is to be found. Buildings, shelves, pages and drawers, etc. provide the continuity of association. The computer screen is, of course, quite abstract in its manifestation, where conceptual associations are not only hard to identify, but hard to understand.

Soderston experimented with various spatial models to determine their effectiveness for human navigation within complex computer interfaces. She was able to document an aggregate preference for a hierarchically based delivery of information, as opposed to a linear presentation. She remarks that the hierarchical model is based on the human structure of memory. Accordingly, such a structure should be amenable to assimilating knowledge of the survey type. In other words, in the context of online searching, an algorithmic based, structured display which provides syntax will affect the user in a way that will be conducive to assimilating the critical survey knowledge.

5 CONCLUSION

It is quite evident that rather significant improvements in interface designs will be required for the end-user searching we will witness in the next decade. It is important to characterize the spatial factors described above to the extent possible, thereby providing a theoretical foundation upon which to direct the aforementioned interface design improvements. The possibilities of graphics, capturing and coding expert searcher algorithms, as well as expert "intermediary" interview techniques, and putting all of this capability and knowledge into a dynamic interface is probably not that far off in our future. We certainly have the problem, which is becoming more acute. We have the tools, certainly the hardware with the new generation of PCs. We now need the interface software, powerful software which addresses human cognitive factors.

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